(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 March 2001 (22.03.2001)

PCT

(10) International Publication Number
WO 01/20125 A1

(51) International Patent Classification[7]: E21B 43/10, 43/08

(21) International Application Number: PCT/GB00/03531

(22) International Filing Date:
14 September 2000 (14.09.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9921557.6 14 September 1999 (14.09.1999) GB

(71) Applicant: **WEATHERFORD/LAMB, INC.** [US/US]; c/o CSC - The United States Corporation Company, 1013 Centre Road, Wilmington, DE 19805 (US).

(71) Applicant and
(72) Inventor: **METCALFE, Paul, David** [GB/GB]; North Wing, Bucklerburn Steading, Peterculter AB14 0NP (GB).

(74) Agents: **MCCALLUM, William, Potter** et al.; Cruikshank & Fairweather, 19 Royal Exchange Square, Glasgow G1 3AE (GB).

(81) Designated States *(national)*: AU, CA, NO.

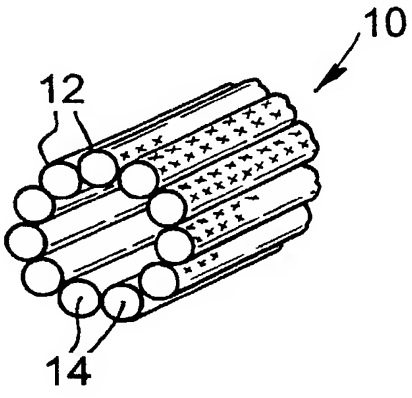
(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: EXPANDABLE TUBING

(57) Abstract: Expandable tubing (20) has a tubing wall (22) comprising a plurality of deformable tubular structures (24). The structures (24) have permeable walls and containing a filter medium (28) such that fluid may flow through the structures (24) and the filter medium (28) and thus through the tubing wall (22).



WO 01/20125 A1

EXPANDABLE TUBING

This invention relates to a downhole apparatus, and in particular but not exclusively to forms of expandable tubing and to forms of expandable filters and filter supports.

WO93/25800 (Shell Internationale Research Maatschappij B.V.) describes a method of completing an uncased section of borehole. A slotted liner provided with overlapping longitudinal slots is fixed in the borehole and a tapering expansion mandrel is pushed or pulled through the liner. The liner is expanded by the mandrel to support the adjacent borehole wall.

WO97/17524 (Shell Internationale Research Maatschappij B.V.) describes a deformable well screen and method for its installation utilising two sections of concentric slotted tubing, such as described in WO 93/25800, with a series of circumferentially scaled filter segments therebetween. The screen is expanded by pushing or pulling an expansion mandrel through the screen.

The expansion mechanism of these arrangements is such that there is an axial retraction of the tubing on radial expansion. This not only creates difficulties in accurately locating and securing the ends of the tubing in a bore relative to adjacent tubing sections, but also may

result in undesirable relative axial movement between the tubing and other elements mounted thereon, such as filter segments. Further, in such a filter arrangement, the radial expansion forces which must be applied to the outer section of expandable tubing are transferred via the filter medium or media located between the tubing sections; this limits the range of media which may be utilised in such arrangements to filter materials and configurations which will withstand significant compressive forces, in addition to the significant shear forces which the filter material will experience during expansion of the tubing sections.

It is among the objectives of embodiments of aspects of the invention to provide alternative expandable tubing forms, including expandable filters and filter supports, which overcome such disadvantages.

According to the present invention there is provided expandable tubing having a tubing wall comprising a plurality of deformable tubular structures, at least some of the structures having permeable walls and containing a filter medium such that fluid may flow through the structures and thus through the tubing wall.

This aspect of the invention is useful as a downhole filter or sand screen, the deformable tubular structures forming the wall of the tubing facilitating expansion of the tubing, and the tubular structures potentially serving as filter elements and also accommodating a selected filter

medium or media. Also, the use of the tubular structures to accommodate or facilitate expansion assists in avoiding the longitudinal contraction which tends to occur on radial expansion of tubing defining overlapping longitudinally extending slots.

The tubular structures may extend longitudinally, helically, or in be positioned in any appropriate orientation. A substantially axial orientation may offer more straightforward assembly and resistance to bending, however for other applications a helical arrangement may offer greater flexibility and resistance to radial compressive forces.

The tubular structures may be of any material, structure or form which provides the desired degree of deformability, permeability and the desired degree of structural strength. In one embodiment, the tubular structures are of sintered ductile metal, while in other embodiments drilled or slotted tubes may be utilised. If sintered metal, or some other porous material of similar structure, is utilised to form the tubular structures, the pores of the material may be initially filled or occupied by another material to create an impermeable structure. This filling material may be subsequently removed, for example by application of an appropriate solvent, which may be produced fluid, or exposure to elevated temperature as experienced in deeper bores.

The tubular structures may be connected to one another by any appropriate method, for example metal structures may be welded or brazed to one another, or the structures may be retained between two expandable sleeves or tubes.

In other embodiments, the tubular structures may be defined by appropriately shaped sheets or elements, or unitary structures, for example two corrugated sheets or tubes which have been welded or otherwise secured together, or by extruding or otherwise forming the tubing wall in a form which incorporates tubular structures. These embodiments may form other aspects of the invention, in which the tubular structures are impermeable, that is fluid is prevented from flowing through the tubing wall, in one or both of the unexpanded and expanded configurations.

The tubular structures may feature substantially continuous walls, or may have discontinuities therein, for example the tubular structures may be substantially C-shaped.

The tubular structures may accommodate a filter medium of media, such as woven wire, porous foam, wire mesh or wire wool, or indeed any medium presently utilised as a filter and which could be located within a tubular structure and withstand the change in shape experienced by the tubular structures during expansion. Alternatively or in addition, the tubular structures may be lined with a filter media in the form of a flexible or deformable porous

material.

The aperture or pore size defined by the tubular structures or the filter media therein may be selected as appropriate, depending on the intended application of the tubing: the tubing may provide a relatively coarse filter, for preventing passage of relatively large solids, or may be such that passage of liquid or very fine solids is prevented or restricted, and only passage of gas is permitted, by use of a tubular structure-lining material such an expanded PTFE, as produced under the Gore-Tex trade mark by W.L. Gore & Associates.

These and other aspects of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of an expandable tubing in accordance with an aspect of the present invention;

Figure 2 shows the tubing of Figure 1 following expansion;

Figure 3 is a diagrammatic representation of part of a wall of an expandable tubing in accordance with a further aspect of the present invention;

Figure 4 shows the tubing of Figure 3 following expansion;

Figure 5 illustrates an expandable tubing in accordance with a still further aspect of the present

invention; and

Figures 6 to 9 are diagrammatic representations of walls of expandable tubings in accordance with further aspects of the present invention.

Reference is first made to Figures 1 and 2 of the drawings, which illustrate a form of expandable tubing 10, in accordance with an aspect of the present invention, and which may be utilised as or as part of a sand screen or other downhole filter arrangement. Typically, the tubing will be run into a bore in the "unexpanded" form as illustrated in Figure 1, anchored in the bore, and then expanded to the larger diameter expanded form as illustrated in Figure 2, with a degree of expansion in excess of 30% being achievable.

The tubing wall 12 comprises a plurality of axially extending tubular structures in the form of small diameter tubes 14 formed of sintered metal. The tubes 14 provide a porous sand filtering media.

Expansion of the tubing 10 is primarily accommodated by a flattening of the tubes 14, and the expanded tubing is shown in Figure 2 of the drawings. This expansion may be achieved by means of a conventional expanding cone or mandrel, which is pushed or pulled through the tubing 10. As the tubes 14 deform there will also be some deformation and variation in the sizes of the pores, apertures and passages in the walls of the tubes, however pore size

variation may be predicted to some extent, and in any event it is difficult to form a porous sintered metal product with closely controlled pore size.

Reference is now made to Figures 3 and 4 of the drawings, which illustrate part of an alternative expandable tubing 20, in which the tubing wall 22 comprises a plurality of solid tubes 24 having holes 26 drilled therein. The tubes 24 accommodate filter media 28 which may be in the form of deformable woven wire, porous foam, wire mesh or wire wool. On expansion of the tubing, to the form illustrated in Figure 4, the aperture or pore size of the filter media 28 will not tend to change (although the filter media may be subject to some compaction), providing a greater degree of predictability than the tubing 10 described above.

Reference is now made to Figure 5 which illustrates a similar form of expandable tubing 40 to that shown in Figure 1, except that the pores 42 of the material forming the tube walls are initially filled by another removable material 44 thus (temporarily) creating an impermeable structure. This filling material 44 may be subsequently dissolved, or removed by exposure to elevated temperatures.

Figure 6 illustrates a further alternative embodiment of the present invention in which the tubular structures 52 are retained between two expandable sleeves 54, 55

Figure 7 illustrates a wall section 60 of tubing 60 of

a further embodiment of the present invention wherein the tubular structures 62 are defined by inner and outer corrugated sheets 64, 66. These sheets 64, 66 are welded together at 68.

Reference is now made to Figure 8, which shows a wall section of tubing 70 of another embodiment of the invention, which tubing features an alternative form of tubular structures 72 to define the bounding walls of the expandable tubing 70. In this particular example, the tubular structures 72 do not have continuous walls, being substantially C-shaped.

Figure 9 illustrates a wall section of tubing 80 of a further embodiment of the invention. In this embodiment, the porous tubular structures 82 are lined with a filter membrane 84. In this example the membrane 84 is a flexible porous material, in particular expanded PTFE, as sold under the GORE-TEX trade mark, and is impervious to selected liquids, and only permits passage of gas therethrough.

It will be apparent to those of the skill in the art that the above-described embodiments are merely exemplary of the various aspects of the present invention, and that various modifications and improvements may be made thereto without departing from the scope of the present invention.

CLAIMS

1. Expandable tubing having a tubing wall comprising a plurality of deformable tubular structures, at least some of the structures having permeable walls and containing a filter medium such that fluid may flow through the structures and the filter medium and thus through the tubing wall.

2. The tubing of claim 1, wherein the tubing is adapted to prevent flow of particulates through the tubing wall.

3. The tubing of claim 1 or 2, wherein the tubular structures extend longitudinally of the tubing.

4. The tubing of any of the preceding claims, wherein the tubular structures are of sintered ductile metal.

5. The tubing of any of the preceding claims, wherein the tubular structures are of porous material and the pores of the material are initially filled by another removable material to create an initially impermeable structure.

6. The tubing of any of claims 1, 2 or 3, wherein the tubular structures are apertured tubes.

7. The tubing of any of the preceding claims, wherein the tubular structures are retained between two expandable sleeves.

8. The tubing of any of claims 1 to 6, wherein the tubular structures are defined by corrugated members.

9. The tubing of any of the preceding claims, wherein the tubular structures have substantially continuous walls.

10. The tubing of any of claim 1 to 8, wherein the tubular structures have discontinuities therein.

11. The tubing of claim 10, wherein the tubular structures are substantially C-shaped.

12. The tubing of any of the preceding claims, wherein the tubular structures are lined with a filter medium.

13. The tubing of claim 12, wherein the filter medium lining is a flexible porous material.

14. The tubing of claim 13, wherein the flexible porous material is adapted to prevent passage of selected liquids therethrough but to permit passage of gas therethrough.

15. Expandable tubing having a tubing wall comprising a plurality of deformable tubular structures, at least some of the structures having porous walls of sintered ductile material such that fluid may flow through the structures and through the tubing wall.

16. Expandable tubing having a tubing wall comprising a plurality of deformable tubular structures, at least some of the structures having walls of porous material initially filled by another removable material to create an initially impermeable structure, such that upon removal of said removable material fluid may flow through the structures and thus through the tubing wall.

17. Expandable downhole tubing having a tubing wall comprising a plurality of deformable tubular structures retained between two expandable sleeves.

18. Expandable downhole tubing having a tubing wall comprising a plurality of deformable tubular structures defined by a plurality of corrugated members.

19. The tubing of claim 18, wherein at least some of the structures have permeable walls such that fluid may flow through the structures and thus through the tubing wall.

20. Expandable downhole tubing having a tubing wall comprising a plurality of deformable tubular structures, the tubular structures having discontinuities therein.

21. The tubing of claim 20, wherein at least some of the structures have permeable walls such that fluid may flow through the structures and thus through the tubing wall.

22. The tubing of claim 20 or 21, wherein the tubular structures are substantially C-shaped.

23. Expandable tubing having a tubing wall comprising a plurality of deformable tubular structures, at least some of the structures having permeable walls lined with a filter medium such that fluid may flow through the structures and the filter medium and thus through the tubing wall.

24. The tubing of claim 23, wherein the filter medium lining is a flexible porous material.

25. The tubing of claim 24, wherein the flexible porous material is a membrane adapted to prevent passage of selected liquids and permit passage of gas therethrough.

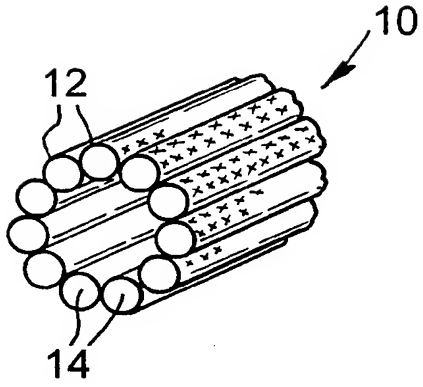


Fig.1

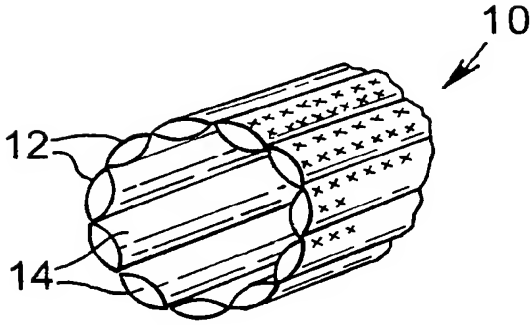


Fig.2

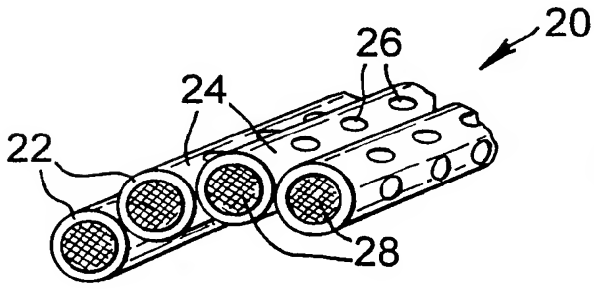


Fig.3

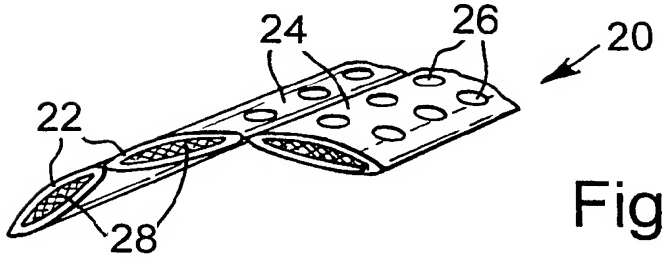


Fig.4

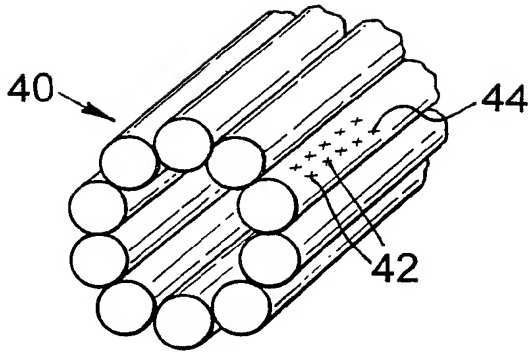


Fig.5

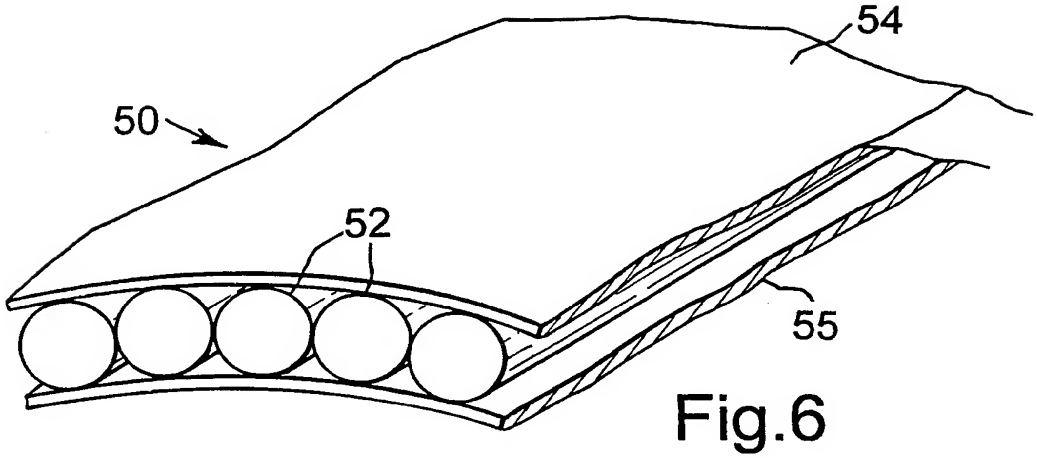


Fig.6

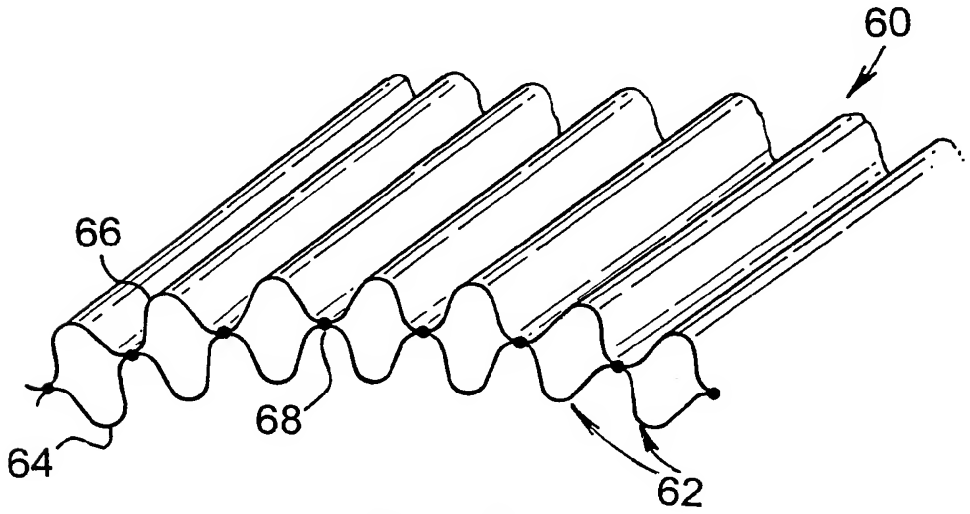


Fig.7

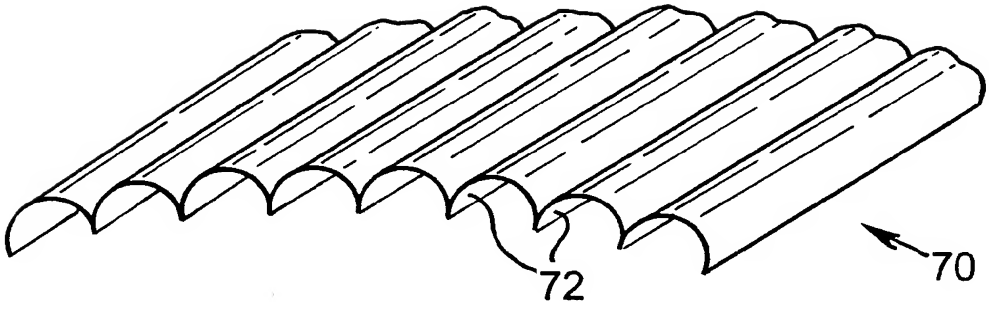


Fig.8

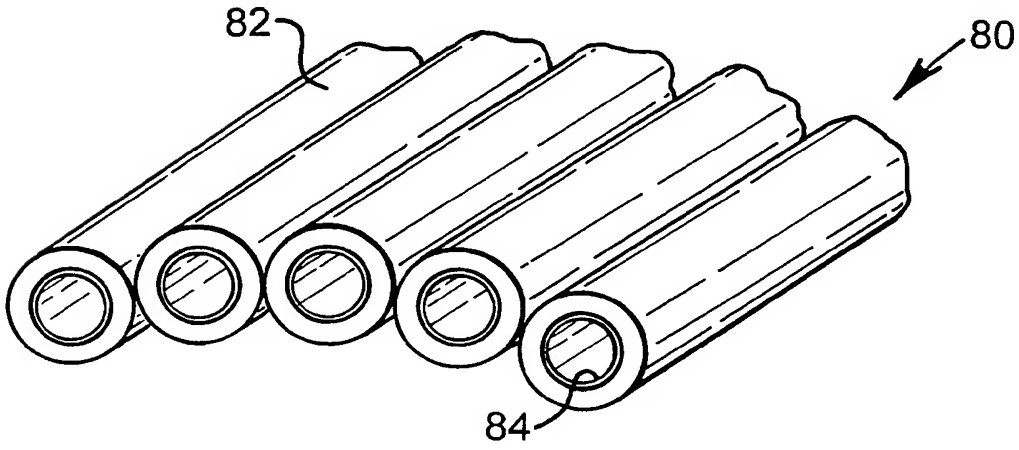


Fig.9

INTERNATIONAL SEARCH REPORT

Inter ɔnal Application No
PCT/GB 00/03531

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/10 E21B43/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	EP 0 952 305 A (SHELL INT RESEARCH) 27 October 1999 (1999-10-27) column 4, line 5 - line 7 column 4, line 19 - line 23 column 6, line 22 - line 32 ---	15,20,21
X	EP 0 937 861 A (HALLIBURTON ENERGY SERV INC) 25 August 1999 (1999-08-25) figure 7 ---	18
A	US 3 353 599 A (GULF OIL CO) 21 November 1967 (1967-11-21) column 4, line 71 -column 5, line 10 ---	1-25
A	FR 721 430 A (KAPFERER HENRI) 3 March 1932 (1932-03-03) page 2, line 14 - line 32 ---	1-25

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2000	24/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Garrido Garcia, M

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter onal Application No
PCT/GB 00/03531

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 901 789 A (KENTER CORNELIS JAN ET AL) 11 May 1999 (1999-05-11) column 4, line 56 - line 59 figures 1,2 ---	1-25
A	FR 2 326 229 A (GRIHANGNE ANDRE) 29 April 1977 (1977-04-29) figures 1-12 -----	1-25

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter ›nal Application No
PCT/GB 00/03531

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0952305 A	27-10-1999	AU 4361099 A	16-11-1999
		WO 9956000 A	04-11-1999
EP 0937861 A	25-08-1999	BR 9900483 A	18-01-2000
		NO 990784 A	25-08-1999
US 3353599 A	21-11-1967	NONE	
FR 721430 A		NONE	
US 5901789 A	11-05-1999	AU 710745 B	30-09-1999
		AU 7568096 A	29-05-1997
		BR 9611456 A	17-02-1999
		EA 980433 A	29-10-1998
		WO 9717524 A	15-05-1997
		EP 0859902 A	26-08-1998
		JP 11514712 T	14-12-1999
		NO 982087 A	07-07-1998
		NZ 322015 A	28-10-1999
		US 6012522 A	11-01-2000
FR 2326229 A	29-04-1977	NONE	